Sir J. J. Thomson, remains undecided. The method already furnishes, however, a very direct proof that when ionisation by X-rays occurs corpuscles are liberated, each with energy sufficient to enable it to produce a large number of ions along its course.

The few preliminary photographs which have been taken were not obtained under conditions suitable for an examination of the relation of the initial direction of the cathode rays produced in the air to that of the incident Röntgen radiation. I hope shortly to obtain photographs which will admit of this being done.

The Vacuum Tube Spectra of Mercury.

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The 'Proceedings of the Royal Society' for 1860 contain a paper by Plücker,* which gives an account of the first observations of the spectrum of the luminous discharge through mercury vapour at a low pressure. Plücker used a vacuum tube with mercury electrodes, and he observed and made measurements of the wave-lengths of ten lines. A few years later, working with Hittorf,† he found that the mercury spectrum may be obtained more brightly when a Leyden jar and spark gap are used in parallel with the tube. Other conditions affecting the lines observed in the vacuum tube spectrum of mercury have since been recorded by various investigators; for instance, the widening of the lines with increased pressure was observed by Ciamician,‡ and the effect of the presence of different gases in the vacuum tube on the brightness of the mercury lines was investigated by Sundell,§ who found that the mercury lines were visible when the tube contained hydrogen at considerable pressures, but that with oxygen or nitrogen they could only be seen when the pressure was very low.

The spectrum of the light from the mercury arc was first investigated by Liveing and Dewar,‖ and afterwards very completely by Kayser and

* Plücker, 'Roy. Soc. Proc.,' 1860, vol. 10, p. 256.

† Plücker and Hittorf, 'Phil. Trans.,' 1865, vol. 155, p. 1.

‡ Ciamician, 'Wien. Ber.,' 1878, vol. 78, p. 867.

§ Sundell, 'Phil. Mag.' [5], 1887, vol. 24, p. 98.

‖ Liveing and Dewar, 'Phil. Trans.,' 1883, vol. 174, p. 187.

Runge,* but the first thorough investigation of the spectrum of mercury in vacuum tubes was that of Eder and Valenta,† published in 1894. These observers found that the lines obtained from a vacuum tube at low pressures were much sharper than those given by the arc or spark. The number of lines obtained depended on the current density and on the temperature of the vapour. The spectrum richest in lines was obtained by having one part of the vacuum tube hot and the rest cold, so that the mercury distilled through the capillary. Using a Leyden jar they were then able to measure a great many new lines. From the wider parts of the vacuum tube they obtained a banded spectrum, but this (which was first observed by them) was seen best in the capillary when the discharge was passed without a Leyden jar. Introducing capacity into the circuit had the effect of breaking up these bands into an immense number of fine lines—the "rich line spectrum"—some 670 lines are recorded in their paper.

The observations of Eder and Valenta have since been confirmed by Huff.‡ As the result of a detailed study of the effects of capacity, self-induction, and temperature on the spectrum, he came to the conclusion that, by suitably regulating the temperature of the tube and the conditions of the discharge, the spectrum could be made to change gradually from that consisting of bands to that richest in lines. A background of continuous spectrum was obtained, especially when capacity was placed in the circuit and strong discharges were passed at rather high temperatures.

A thorough investigation of the spectrum of mercury has also been made by Stark,§ who came to the conclusion that mercury possesses two distinct line spectra, viz., that given by an arc *in vacuo*, and that given by a vacuum tube discharge. The lines obtained in the arc spectrum were those previously observed by Kayser and Runge, together with a few others of small intensity. Those obtained in the spectrum of the glow discharge Stark compares with the "rich line spectrum" of Eder and Valenta. The latter observers give more lines in the less refrangible part of the spectrum, but Stark records many more in the ultra-violet. The spectrum given by the mercury arc light is called by Stark the first line spectrum of mercury, that given by the glow discharge is the second line spectrum. He puts forward the hypothesis that the first line spectrum is due to monovalent, and the second line spectrum to divalent mercury atoms—atoms which have lost respectively one and two negative corpuscles.

* Kayser and Runge, 'Wied. Ann.,' 1891, vol. 43, p. 384.
† Eder and Valenta, 'Denkschr. Wien. Akad.,' 1894, vol. 61, p. 401.
‡ Huff, 'Astrophys. Journ.,' 1900, vol. 12, p. 103.
§ Stark, 'Ann. d. Phys.,' 1905, vol. 16, p. 490.

A very complete investigation of the vacuum tube spectrum of mercury has been made by Stiles,* who gave particular attention to the red end, a region of the spectrum which has not been so closely investigated as those which more readily affect a photographic plate. While investigating the discharge of electricity for a hot lime cathode in a vacuum tube, the author† was struck by the appearance of five sharp, bright lines in the red and orange regions of the spectrum, lines which could not be found recorded in any of the ordinary tables of wave-lengths, although two of them agreed roughly with faint lines observed by Stark in the vacuum tube spectrum of mercury. It now appears that these lines had been previously observed and measured by Hermann‡ in the arc spectrum of mercury. They have since been measured by Stiles and their wave-lengths recorded in the paper already referred to.

These lines are so sharp and bright in the spectrum of the discharge from a hot lime cathode through mercury vapour, that I was tempted to investigate the spectrum of the discharge in an ordinary vacuum tube under different electrical conditions. It was found that under certain conditions several new red and orange lines could be obtained. These appeared when a condenser was used, and the discharge was sent through the vapour at a low pressure. I therefore tried the effect of varying the pressure of the vapour through which the discharge from a hot lime cathode passed, in order to see if a different spectrum could be obtained. The discharge tube used was of the form figured in my previous paper, except that the platinum anode was covered with mercury. The amount of vapour present in the tube could be varied by warming or cooling it. When the lime cathode was heated and a discharge from a battery of cells passed through the tube, the five red and orange lines were seen quite brilliantly, the other bright lines observed being the two yellow lines 5791, 5770, the green 5461, the blue 4916, and the violet 4359. On increasing the vapour pressure by warming the mercury, all the lines became wider and blurred and, with the exception of the wave-lengths just mentioned, they finally became indistinguishable in a brilliant background of continuous spectrum. On reducing the pressure of the vapour by cooling the tube in liquid air, the whole spectrum became very faint and finally disappeared as the luminosity ceased, the lines in the red and orange regions being the first to go.

It thus appears that the normal spectrum produced by the lime cathode discharge through mercury vapour contains these five red and orange lines

* Stiles, 'Astrophys. Journ.,' 1909, vol. 30, p. 48.

† Horton, 'Camb. Phil. Soc. Proc.,' 1908, vol. 14, p. 501.

‡ Hermann, 'Ann. d. Phys.,' 1905, vol. 16, p. 684.

in addition to the other bright ones mentioned above; a few faint lines are also visible—the complete spectrum is given in Column II of the table on p. 295. As will be seen in the following pages, this spectrum can also be obtained, under certain conditions, from the induction coil discharge through an ordinary vacuum tube.

The Preparation of the Vacuum Tubes.

In the investigations of the spectrum of the induction coil discharge through mercury vapour the vacuum tubes employed were of the shape indicated in the accompanying diagrams :—

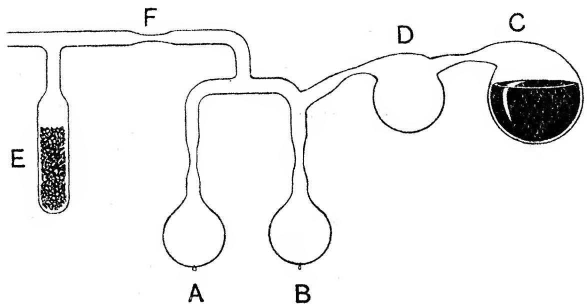

FIG. 1.

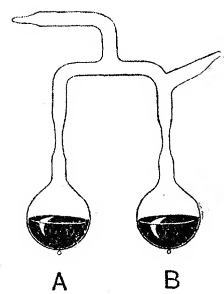

FIG. 2.

Fig. 1 shows the tube before being filled with mercury; fig. 2 shows it sealed off from the pump and ready for use. The bulbs A and B containing the mercury were each about 2 cm. in diameter. The capillaries were about 2 mm. wide, but differed slightly in width in the different tubes used.

The method of getting the mercury into the vacuum tube in a high state of purity may be gathered from fig. 1. The glass tubing used to make the apparatus there shown was most carefully cleaned with chromic acid, and when complete the apparatus was cleaned out with boiling nitric acid, and finally with distilled water. Boiling nitric acid in the bulbs A and B served to remove hydrogen from the small platinum electrodes fused into them. After careful drying, the discharge tube AB with the bulb D was sealed on to a mercury pump with a phosphorus pentoxide drying tube and the tube E containing cocoanut charcoal in connection. The large bulb C was carefully cleaned, dried, and nearly filled with purified mercury. It was then sealed on to the bulb D as shown in the diagram. The whole apparatus was exhausted as completely as possible by means of the mercury pump, the evacuation being finally completed by cooling the carbon tube E in liquid air. The tube AB and the bulb D were then heated all over by means of a blow-pipe flame to remove gas occluded on the inside surface of the glass.

The heating was continued for half an hour or more, and the glass was made so hot that in places it softened and sank in on account of the vacuum inside. The bulb C was then very gently warmed by means of a small flame placed about 20 cm. below it, and the mercury began to distil over and to collect in the bulb D. When about two-thirds of the mercury in C had distilled into D the small connecting tube was fused up by a blow-pipe flame, and C was removed from the apparatus. D was then gently warmed, and two-thirds of the mercury in it was distilled over into the discharge tube AB. D was then sealed off and removed. The mercury in the bulbs A and B was heated, and a discharge from an induction coil was passed through the tube. After this had been going on for some time the temperature of the discharge tube was considerably raised by gentle heating with a blow-pipe flame, and a quantity of the mercury distilled over into the tubes leading to the pump and collected there and in the tube E, which, throughout these operations, remained in a vessel of liquid air. Finally the connecting tube was melted at F, where previously it had been drawn down, and the discharge tube was separated from the pump and was ready for use (fig. 2). In this manner tubes could be prepared containing mercury only, all traces of foreign substances being completely excluded. At the ordinary room temperature the vacuum in the tube was so complete that no discharge could be sent through it by a large Marconi coil giving a 10-inch spark.

In one of the tubes used the mercury was prepared from pure mercuric oxide supplied by Kahlbaum. This was decomposed by heating it in a vacuum, the oxygen being continually pumped away. The mercury was distilled into the discharge tube in the manner already described. All the tubes used gave similar spectra, but in one or two of them the carbon monoxide band spectrum was sometimes seen after they had been in use for some weeks, and, strangely enough, generally when the pressure of mercury vapour in the tube was rather high. I think that this gas came from the glass of the discharge tube, for the inner surface of the bulbs A and B at the level of the mercury became broken up by the passage of the discharge, and this might lead to a liberation of CO_2 (which gives the band spectrum) from carbonates used in the manufacture of the glass. This would account for the spectrum appearing when the pressure of the mercury vapour was high, for then the tube was being most strongly heated. However, I have one tube, made over two years ago, which has never shown anything but mercury lines.

The Spectroscope, etc.

The spectroscope used to measure the wave-lengths of the lines was one of Hilger's direct wave-length reading instruments. This was very carefully calibrated by means of a helium-hydrogen-mercury tube. It was further calibrated in the red, orange, and yellow, by means of a neon tube. A curve of corrections was plotted showing the correction to be applied to any reading when the instrument was adjusted so that the reading of the mercury orange line, 6152, was correct.

The mercury vacuum tube under observation was held in a wooden stand, and under each of the bulbs A and B, but some 20 cm. below them, was placed a small flame which could be adjusted in size. The coil used to produce the discharge was a large Marconi instrument, taking 3 to 12 ampères through the primary, and capable of giving a 10-inch spark in the secondary circuit.

When extra capacity was required in the circuit, two large Leyden jars of gallon size, joined in parallel, were included. This was done by lessening the size of a spark gap until sparks passed between the knobs, or sometimes by screwing these knobs up together. It was found that the two jars in parallel had more effect on the spectrum than one jar alone, and the effect was not noticeably increased by using six jars. The appearance of the spectrum varied greatly with the size and nature of the spark between the knobs in the Leyden jar circuit, the spectrum with most lines being observed when sharp, bright, intermittent sparks passed.

Experimental Results.

In the experiments with the mercury vacuum tubes described in this paper, several spectra were obtained which appeared to be produced by quite definite conditions. These spectra contained, in some cases, the same lines, but with different relative intensities. Each spectrum was quite distinct and easily recognisable, and could be made to appear on arranging the electrical conditions known to produce it. The methods of obtaining the different spectra will now be described.

The simplest spectrum is that which I have called the five-line spectrum of mercury, consisting of the yellow pair 5791, 5770, the green 5461, the blue 4916, and the violet line 4359. This spectrum is always obtained when both limbs of the tube are fairly hot and the discharge is running easily, the interrupter of the induction coil working quietly and without much sparking. Under these circumstances, even with the knobs of the spark gap in connection with the Leyden jars close together, no spark (or a very small and quiet one) passes between them, and screwing them together until they touch

causes no difference in the spectrum of the discharge. During these observations, mercury condenses and collects in the upper, horizontal part of the tube. This suddenly runs over into one or other of the limbs of the tube, and some of it falls down into the mercury in the bulb, but generally a blob remains, blocking up a portion of the capillary. This immediately changes the nature of the discharge; sparks are heard between the knobs of the spark gap, and usually the induction coil works more noisily. Instead of the simple five-line spectrum, the lines recorded in column II of Table I appear. This spectrum is the one given by the discharge from a glowing lime cathode through mercury vapour, and its characteristic feature is that the three orange lines 6235, 6124, 6074, are present and are equally bright.

During this experiment both bulbs, A and B, fig. 2, have been gently warmed. If, now, the flame under bulb A is turned out, so that the temperature of that limb of the tube falls and the mercury distils over from B to A, and if the tube is then gently tapped with the finger so that a blob of mercury is made to collect in one of the capillaries, at the instant the blob forms the luminosity of the tube increases, and the spectrum observed is that given in column III of Table I. The most noticeable features of this are the presence of the mercury orange line 6152, and that, of the other three orange lines, which in Spectrum II are equally bright, 6235 is now brighter than 6124 or 6074. The order of luminosity of the two red lines is now reversed, and many more lines appear in the more refrangible parts of the spectrum. On the other hand, the two faint, but sharp, lines 5352, 5319, of Spectrum II are now no longer seen. In this experiment the mercury vapour is at a fairly high pressure, though, of course, not at quite so high a pressure as in the first experiment, in which both bulbs were heated. The spectrum obtained before the blob appears in the tube is the five-line spectrum, and, as before, this is not altered by putting the capacity in the circuit by screwing up the spark gap. Spectrum III is given by the light from either capillary after the blob has formed in one of them. There is a lot of continuous spectrum as a background to these lines; this disappears when the blob falls out of the capillary, and the five-line spectrum then becomes very bright again. The other lines generally persist faintly for a short time, but they soon disappear. This seems to indicate that the systems emitting them are no longer being produced in the vapour, but that those which existed at the moment the blob fell out of the capillary are not immediately destroyed when the electrical conditions are changed. The formation of the blob of mercury in the capillary has the effect of making the tube "harder"; for the two fresh surfaces of mercury formed across the tube act as an extra

Table I.

I.		II.		III.		IV.		V.	
Five-line spectrum.	Intensity.	Spectrum of glowing lime discharge.	Intensity.		Intensity.		Intensity.	Lines measured by Eder and Valenta.	Intensity.
		6908	1	6908	3				
		6717	4	6717	2				
		6235	8	6235	8				
				6152	8	6152	8	6152	9
		6124	8	6124	5				
		6074	8	6074	5				
				5890	6	5890	3	5889	4
				5873	2	5873	3	5872	6
				5819	1			5819	1
				5806	2			5804	1
5791	9	5791	8	5791	8	5791	8	5791	10
5770	9	5770	8	5770	8	5770	8	5770	10
						5728	1*s*	5728*	5
		5679	1	5679	4	5679	6	5679	8
						5596	2*s*	5596	6
5461	10	5461	10	5461	10	5461	10	5461	10
				5427	1*s*	5427	8	5427	8
				5409	1				
				5366	6			5366	4
				5356	1			5356*	1
		5352	1*s*					5352*	1
		5319	1*s*						
						5207	1*b*	5207	4
						5128	1*b*		
				5047	3			5047	1
				4960	4	4960	1*b*	4960	6
4916	4	4916	4	4916	6	4916	1*b*	4916	4
						4797	1*b*	4797	2
4359	10	4359	6	4359	8	4359	8	4359	10

The lines of Eder and Valenta marked with an asterisk were only observed in the many lined spectrum.
b signifies that the line was blurred. *s* signifies that the line was sharp.

anode and extra cathode respectively, and there is consequently a double anode fall and a double cathode fall of potential to be overcome by the E.M.F. applied from the induction coil. The result of this is that a larger potential difference is established between the terminals of the tube. The Leyden jars become charged to a higher potential, and the energy of the discharge is now much greater than before, as is shown by the difference in the sparks. This increase in the energy of the discharge is possibly the cause of the production, and certainly the cause of the agitation, of those vibrating systems which are the origin of the extra lines appearing in the spectrum when the mercury collects in the capillary of the tube.

That an increase in the energy of the discharge, due to an increase in the difference of potential between the terminals of the tube, is the cause of the

appearance of these extra lines may be shown in another way, for, starting with both bulbs fairly warm and the discharge running easily, we can increase the potential gradient in the tube by lowering the flames and allowing the temperature, and therefore the pressure, of the mercury vapour to fall. Doing this, we find that the five-line spectrum changes into Spectrum II, without the blob of mercury forming in the capillary. The temperature at which this happens is lower than that at which Spectrum III is produced in the experiment described above. Having obtained Spectrum II in this manner, we can suddenly still further increase the potential gradient by tapping the tube so that the mercury collects in the capillary. The spectrum at once changes in a remarkable manner; the orange line 6152 comes out brilliantly, and is the *only* line in that part of the spectrum—the other orange and the red lines disappear. The visible lines are recorded in column IV of Table I. When the mercury falls out of the capillary the spectrum changes back again to Spectrum II. It is interesting to note that just as Spectrum II could be produced without the formation of the blob of mercury in the capillary, so, at still lower pressures, Spectrum IV would appear in the same way. It was seen on several occasions after turning out both the Bunsen burners under the tube and allowing it gradually to cool down. On these occasions there was a small spark gap (about 0·5 mm.) in the Leyden jar circuit, and feeble sparks passed across. If the pressure falls too low, heavy sparking occurs and many more lines appear in the spectrum.

The behaviour of the orange line 6152 is peculiar. Its appearance seems to depend upon circumstances which only slightly affect other lines usually appearing with it. For instance, when one limb only of the tube was warmed and the pressure of the vapour inside was not too low, the five-line spectrum normally changed into Spectrum III when a blob of mercury collected in the capillary, but sometimes all the lines of this spectrum would appear except 6152. On these occasions, by careful observation, the line could usually be seen very faintly, and it would suddenly flash out quite brilliantly for an instant, probably during some slight change in the electrical conditions. At the same time several of the other lines would momentarily increase in brightness, notably the yellowish-green line 5679. It might here be mentioned that I made some experiments with mercury vacuum tubes containing a little helium gas, in order to have present some lines of known wave-length for standardising the readings of the spectrometer. It is well known that the presence of helium brings out the mercury orange line very brightly, when otherwise only the five-line spectrum would appear. I found that the helium lines and the mercury line 6152 always

appeared and disappeared together as the electrical conditions were changed. They were visible when an induction coil discharge was passed with the mercury electrodes cold, but when these were heated so as to increase the vapour pressure in the tube, the helium lines would gradually get fainter and finally disappear, and so also would the mercury orange line; at the same time the other five mercury lines (Spectrum I) would gradually increase in brightness. Similar results were obtained when the discharge from a glowing lime cathode was used to produce the luminosity, although in this case the helium spectrum was always faint, and in this case, too, the other lines of Spectrum II appeared at first, but faded away as the temperature was raised. The normal cathode fall of potential in helium gas is considerably less than that in mercury vapour, and the presence of helium would therefore probably increase the potential gradient along the rest of the tube, but it is evident that neither a decreased cathode fall nor an increase in the potential gradient along the luminous discharge can be the cause of the production of the line 6152, for in the absence of helium it does not appear in the spectrum of the glowing lime discharge, although the cathode fall is always very small and the potential gradient can readily be varied, nor would such an explanation account for the intimate connection of this particular mercury line with the brightest lines of the helium spectrum.

In regard to the lines recorded in Table I, it should be stated that those down to the bright yellows 5791, 5770, were measured as accurately as possible with the spectrometer used, which had been standardised in the manner already described. The more refrangible lines were merely identified from the measurements of Eder and Valenta, which are given in the last column.

It has already been stated that at very low pressures a spectrum was obtained containing several new red and orange lines. This spectrum in the more refrangible portions corresponds to the many lined spectrum discovered by Eder and Valenta. It was first observed on turning out both the flames used to heat the vacuum tube and allowing it to cool down, but under these circumstances the tube soon becomes so hard that the discharge through it ceases. However, by careful regulation of the size of the flames and the distance of them from the tube, the temperature can be so adjusted that the many lined spectrum is continually present. It is necessary to have the Leyden jars in the circuit, and the spectrum is brightest when loud intermittent sparks pass between the knobs of the spark gap. If the sparks are weaker and give a continuously hissing noise (as they do when the pressure is not sufficiently low) only about half the number of lines are seen. The

many-lined spectrum can be obtained at a slightly higher pressure by arranging that some mercury should collect in one of the capillaries of the tube. Under these circumstances the spectrum is brighter than at the very low pressure, but under the latter condition the lines are all quite sharp, whereas some of them appear blurred and obscured by bands at the higher pressures. The red and the orange lines only of this spectrum are given in Table II, which for comparison also contains the lines previously observed by Hermann and by Eder and Valenta.

Table II.—The Red and Orange Lines of the Many Lined Spectrum.

Lines measured in the present research.	Intensity.	Lines measured by Hermann.	Intensity.	Lines measured by Eder and Valenta.	Intensity.
		7083	1		
(6908)		6908	4		
(6717)		6717	1		
6524	3				
6521	2				
6504	4*i*				
6421	2				
6397	3				
6386	2				
6363	4			6364	2
6347	3*i*				
6318	6*i*				
6298	1				
6292 }	6*i*				
6290 }	1*i*				
6268	1				
6242	2				
(6235)	2	6235	10		
6219	2				
6187	1				
6171	3*s*				
6152	10			6152	10
(6124)	2	6124	10		
6101	2				
6090	2				
(6074)	2	6073	10		
6046	2*s*				
6023	2*s*				
6018	2				
5963	1				
5948	1				
5936	1*s*				
5890	7	5890	2	5889	4
5881	2			5881	2
5873	7	5872	1	5872	6

i signifies that the line was intermittent; the intensity given is that of the line at its brightest.
s signifies that the line was sharp.
The lines 6292, 6290, usually alternated, first one, then the other, appearing in rapid succession.

On a few occasions lines were seen in the red beyond 6524, but I was unable to measure the position of these with any accuracy on account of

their feeble intensity. They appeared to be the two lines 6908, 6717, each of intensity less than 1, with other rather brighter, but very indistinct lines at about 6642, 6604, and 6555. I am inclined to think that the five red and orange lines of the spectrum of the glowing lime discharge (which are placed within brackets in the table) do not properly belong to the many-line spectrum, for they were absent when the spectrum was at its best. If the conditions of the discharge slightly changed, however, the three orange lines 6235, 6124, 6074, would appear, and often when the mercury fell out of the capillary the spectrum would change to Spectrum II of Table I with these lines extraordinarily brilliant. After a few seconds—probably as the temperature fell—hissing sparks would be heard between the knobs of the spark gap and several lines of the many-lined spectrum would appear. The sparks would change to loud intermittent ones when the condensed mercury fell and stopped up the capillary, and then the complete many-lined spectrum could again be observed.

In the table a few of the lines are marked as intermittent; these, as a rule, kept flashing in at very frequent intervals, but in the case of 6318 the line was present all the time and kept flashing out more brightly. These intermittent lines were the last to appear in the many-lined spectrum as the pressure of the mercury vapour in the tube fell.

It has been mentioned that when the many-lined spectrum was obtained at the higher pressure by waiting for a blob of condensed mercury to collect in the capillary of the tube, some of the lines were blurred and obscured by bands. As examples of this: a faint band occurs between the lines 5963 and 5936, but when the many-lined spectrum is at its best this goes, and the line 5948 is seen quite plainly, while the line 5936 becomes extremely sharp. In the same way a band between the lines 6046 and 6018 at the higher pressure disappears when the pressure is reduced, leaving the line 6023 sharply defined.

The many-lined spectrum may conveniently be obtained in another way, by passing an electrodeless ring discharge through mercury vapour. This was done with the tube shown in fig. 2 in the following manner:—The tube was placed on its side and most of the mercury was collected in the bulb B. The bulb A was surrounded by a coil of 10 turns of well-insulated wire, the ends of which were each connected to the outer coating of a large Leyden jar. The inside coatings of these jars were connected to the induction coil with an electric valve in series. An adjustable spark gap was arranged between the two inside coatings, and as each spark passed across this, there was a luminous ring discharge in the bulb A, if the temperature of the tube was first adjusted so that the pressure of the mercury vapour was within certain

limits. The author had previously found* that very bright luminosity may be produced in a gas in this way at pressures as low as 0·03 mm.—corresponding in this case to a temperature of about 60° C.

The electrodeless discharge only gives the complete many-lined spectrum when the slit of the spectroscope is directed to the outer edge of the luminous ring. Fewer lines were seen on looking nearer to the centre of the bulb, where the field is less intense, but these were always lines belonging to the many-lined spectrum; the spectra recorded in Table I were never obtained from the electrodeless discharge.

In addition to the red and orange lines recorded in Table II, 66 other lines were measured in the more refrangible parts of the many-lined spectrum. As nearly all of these were identified as lines measured by Eder and Valenta, it was thought to be unnecessary to give them here. It should be mentioned that the lines in the second column of Table II were measured by Hermann in the spectrum of the mercury arc, produced in an Arons lamp. Hermann used a special method of rendering his photographic plates sensitive to the red rays. There can be no doubt that it was the absence of such sensitiveness in the plates used by Eder and Valenta that was the cause of the lines now recorded in this region of the spectrum escaping detection in their experiments.

Summary and Conclusion.

The experiments described in this paper go to prove that mercury is capable of giving several distinct line spectra when subjected to an electric discharge in a vacuum tube. The particular spectrum appearing in any given case depends upon the energy of the discharge in relation to the mass of vapour through which it passes. The five-line spectrum is the one most easily produced, and as the energy is increased, or the pressure of the vapour is diminished, the other spectra recorded in the tables make their appearance in turn. The spectra of Table I are all perfectly definite in appearance, not only in regard to the actual lines they contain, but also as to their relative intensities when the spectrum is fairly bright; moreover, on gradually increasing the energy of the discharge, all the lines of each spectrum in turn appear at the same moment as the electrical conditions become suitable to its production. The many-lined spectrum, on the other hand, is not quite so definite, for the number of lines appearing increases as the energy of the discharge is increased, until all are present. This is well illustrated by the case of the electrodeless ring discharge, in which, as has already been mentioned, the complete many-lined spectrum is only seen in the stronger parts of the field. A similar

* Horton, 'Roy. Soc. Proc.,' A, 1910, vol. 84, p. 434.

result can be obtained with the ordinary vacuum tube discharge in which the electrical intensity is different at different points. It is much greater in the capillary portion than in the wider parts of the tube; and, consequently, when the complete many-lined spectrum is seen in the capillary, there may be many fewer lines in the spectrum of the luminosity at other places. This is the result obtained by Huff, which is referred to at the commencement of this paper. Huff came to the conclusion that the change from the spectrum with fewest lines to that with the greatest number is quite gradual. This is so when we are dealing with the many-lined spectrum all the time—and I class the two spectra of Eder and Valenta (and also those of Stark) together, as being the same spectrum, with many more lines visible in one case than in the other—but this gradual change does not occur in the case of the spectra of Table I, all of which contain many fewer lines.

It will be noticed from the tables that the five lines of Spectrum I are common to all the spectra of mercury, though their relative intensities are not always the same. The spectrum of the glowing lime discharge consists of these plus some others, the brightest being the three lines in the orange region. Spectrum III is practically a combination of Spectra II and IV, together with a few extra lines, the brightest of which is 5366. There are seven lines of Spectra II and IV which do not appear in Spectrum III, but all are of very small intensity. The many-lined spectrum contains all the lines of the other spectra, except the five red and orange lines 6908, 6717, 6235, 6124, 6074. These, though sometimes visible, were always absent when the spectrum was at its best.

In conclusion, the author would like to emphasize the importance, from a spectroscopic point of view, of two of the methods of producing luminosity in a gas which have been employed in these experiments, namely, by using the electrodeless ring discharge, and by the discharge from a glowing lime cathode. The first of these is a very convenient way of obtaining the spectrum with most lines, corresponding to that given by a heavy discharge with capacity in the circuit. The latter method of exciting luminosity is one which should be capable of many applications in spectroscopy, on account of the ease with which the electrical conditions can be controlled.

In many respects mercury would appear to be an ideal substance to use for investigating the origin of spectra, for its vapour is monatomic and is very easily ionised; moreover, it is possible to excite luminosity in it in several ways: by the electric arc or spark, or by the vacuum tube discharge. This latter may be produced (*a*) under a high potential difference, as with an induction coil—and here the conditions may be varied by introducing capacity

and self-induction into the circuit; (*b*) under a low potential difference by means of the discharge from a glowing lime cathode; and (*c*) by electromagnetic induction in the electrodeless ring discharge. Under these different conditions a continuous spectrum, a band spectrum, and spectra with various numbers of bright lines may be obtained. The difficulty is to correlate the observed spectra with the electrical conditions producing them.

The author gladly takes this opportunity of expressing his thanks to Prof. Sir J. J. Thomson for his interest in these experiments, which were carried out in the Cavendish Laboratory, Cambridge.

The Specific Heat of Water.

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(Abstract.)

The object of this investigation was to obtain a basis curve for the specific heat of water, for comparison with specific heat curves of aqueous solutions. Former observers using different methods have obtained widely varying curves; thus for the specific heat of water at 80° in terms of the 15° calorie, the following figures have been given, showing differences of 1 per cent.:—Barnes, 1·0014; Regnault, 1·0081; Lüdin, 1·0113.

For the value in joules of the 15° calorie the following have been found:—Joule, 4·174; Griffiths, 4·198; Barnes, 4·184.

The first part of our investigation is concerned with the determination of the mechanical equivalent of heat in terms of the mean calorie from 13° to 55°, by a method of continuous flow calorimetry. Mercury thermometers were used which could be read to 0°·005. An interval of 40° was taken, so that an error of 0°·01 would not vitiate the result by more than 1 in 4000. Through a Dewar vessel containing about 3 litres of water, in which was an electric heater, there was passed a current of water, entering at about 13° and passing out at about 55°. The vessel was immersed in a bath kept at the same temperature as the contents of the vessel. The top of the vessel was closed by a platinum box kept 10° higher.

The electric heater, and the resistance used in series with it for determining the current by help of a battery of standard cells, were of novel type. Each consisted of a spiral glass tube of small bore into the ends of which were sealed platinum electrodes. The tube is connected with a thermometer tube so that